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Letter of Transmittal

To: Washington State Dept of Ecology
3190 - 160th Avenue SE
Bellevue, Washington 98008-5452

Date: 8/7/92

Job No. 3502-01

Attn: Nnamdi Madakor

Re: Shell Oil Company Harbor Island Terminal

We are sending the following items:

Date	Copies	Description
8/6/92	3	Final
		Background Summary Report
		Shell Oil Company
		Harbor Island Terminal
		Seattle, Washington

These are transmitted:

☐ For your information ☐ For action specified below ☐ For review and comment XXXX For your use ☐ As requested

Remarks

By: Michael Jenkins
Sr. Staff Hydrogeologist
Title:

Copies to: Todd Suhre, Shell Oil Co.

HI-SHELL000835

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**FINAL
BACKGROUND SUMMARY REPORT
SHELL OIL COMPANY
HARBOR ISLAND TERMINAL
SEATTLE, WASHINGTON**

INTRODUCTION

This Background Summary Report is a compilation of currently available environmental information related to Shell Oil Company's Harbor Island bulk fuel storage terminal in Seattle, Washington. The information presented in this report provides the foundation upon which we will develop a Remedial Investigation Work Plan for the site. This Background Summary Report is, and the forthcoming Remedial Investigation Work Plan will be, completed in accordance with Agreed Order No. DE 92 TC-N159 between Shell Oil Company (Shell) and the Washington State Department of Ecology (Ecology).

The Background Summary Report and Remedial Investigation Work Plan are specific to the B, C, D, and E Yards at the existing Shell bulk fuel storage terminal. The A Yard is not specifically part of this investigation. The United States Environmental Protection Agency (EPA) is currently the lead agency responsible for site activities within the A Yard. Ecology, however, will be informed of A Yard activities, and information from A Yard investigations will be incorporated into the Remedial Investigation, as appropriate.

This report presents the following information:

Historical Operations. This section describes the history of industrial activities on or near the current Shell terminal. Activities include the construction of Harbor Island, early industrial development, and historical land uses on or near the current Shell terminal. These are discussed relative to operations, disposal practices, historical releases, and known locations of past or current waste storage areas.

Local Features and Subsurface Conditions. In this section we describe the location of the Shell terminal relative to adjacent properties, including pertinent area boundaries and features and general site physiography. In addition, we summarize available information regarding subsurface conditions at and adjacent to the Shell terminal.

Previous Environmental Assessments. Previous subsurface investigations conducted at and in the vicinity of the site, including results from previous sampling events are summarized in this section in terms of physical and chemical characteristics, identified compounds, and other pertinent information.

Nature and Extent. This section summarizes on- and off-site health and environmental effects posed by compounds identified at the Shell terminal, including chemical types, affected media, release mechanisms, migration pathways, and human and environmental receptors.

HISTORICAL OPERATIONS

In this section we identify and discuss historical industrial activities on or near the current Shell terminal. Activities date to the construction of Harbor Island. We discuss known operations, disposal practices, historical releases, and locations of past or current waste storage areas. Figure 1 is a vicinity map showing the present configuration of Harbor Island and the location of the Shell terminal.

Historical Sources Reviewed

For the purposes of this review, we documented and characterized land use development patterns for the area including the current Shell terminal and the immediately adjacent vicinity. The area roughly includes properties within about one-half block of the Shell terminal. Information sources included:

- Sanborn fire insurance maps (1917, 1929, and 1950);
- City Street Directories (R.L Polk: 1938, 1941, 1944, 1948/49, 1951, 1958, 1960, 1965, 1968, 1970, 1978, 1980, and 1987/88);
- Utility Maps (City of Seattle Water Main Maps: 1918, 1930, and 1949; City of Seattle Engineering Department Engineering Water/Sewer/Storm Drain Maps: 1965 and 1966; City of Seattle Department of Engineering Underground Fuel Pipeline Maps: 1938

and 1946, City of Seattle Department of Engineering Grading and Pavement Maps: 1942, 1949, and 1965).

- Topographic Maps (USGS: Seattle, Washington 1909, reprinted 1922; U.S. Coast and Geodetic Survey: Seattle Harbor, Washington, 1900; U.S. Coast Survey: Duwamish Bay, Washington, 1854 and 1895; Seattle Harbor showing harbor line as laid down by the Harbor Line Commission, October 28, 1895);

- Law Engineering, Inc., 1988. Draft Report of Site Hydrogeological Assessment, Harbor Island, Seattle, Washington, Shell Oil Company Bulk Fuel Distribution Terminal;

- East Waterway Dock and Warehouse Company, 1918. Promotional Brochure, Loman and Hanford, Seattle;

- DNR Archive Record, 1904. Seattle Tideland Fill in (1895-1904): Tideland, Shoreland, and Waterfront General Files; State Archive Record Group 9/5-60, Dept. of Natural Resources/Commissioner of Public Lands; and

- Verbal information provided by Shell Oil Co., D.W. Close, and Texaco, Inc.

Hart Crowser also obtained and reviewed the following available file reports from the Headquarters Office of Ecology:

- Ebasco Services, Inc., 1990, Phase I Remedial Investigation, Harbor Island Site, Seattle, Washington: EPA Work Assignment Number 253-10L21, July 1990.

- Battelle Northwest (ERC) and Converse GES, 1989, Seafab Metals Corporation RCRA 3013 Assessment Report: November 1989;

- Engineering Enterprises, Inc., 1987, Subsurface Environmental Assessment, ARCO Harbor Island Terminal, ARCO Petroleum Products Company, Seattle, Washington: Engineering Enterprises, Inc., Project Number 512-223, prepared for ARCO Petroleum Products Company, October 5, 1987;

- GeoEngineers, Inc., 1988, Report of Subsurface Contamination Studies, Terminal 18, Port of Seattle, Harbor Island, Seattle, Washington, prepared for Port of Seattle, November 28, 1988;
- Geraghty and Miller, Inc., 1988, Results of the Remedial System Evaluation/Design Phase and Plan for Implementation of the System, ARCO Harbor Island Terminal, Seattle Washington, Project No. WA0536HI01;
- Groundwater Technology, 1986, Preliminary Leak Investigation at Texaco Sales Terminal Harbor Island; and June 4 and August 7, 1986 letters from Groundwater Technology to Texaco, U.S.A.; and
- Roy F. Weston, Inc., 1988, Site Assessment Report, Seattle Iron & Metals Corporation, Seattle, Washington, prepared for Seattle Iron and Metals Corporation, October 28, 1988.

From the sources of information listed, we compiled a list of commercial and industrial facilities within the study area as shown in Table 1. Our experience has shown that this method documents most of the facilities in the area. A limited number of short-lived operations may have escaped detection, however. Limited information was available for the period before about 1920.

Limitations

This review provides an overall understanding of the types of chemical compounds in soil and groundwater beneath the Shell terminal. The nature and limitations of historical research do not purport to identify all activities that may have resulted in possible chemical releases.

Harbor Island Fill History and Early Industrial Development

Harbor Island Construction and Filling

The Harbor Island area originally consisted of deltaic tidal flats at the mouth of the Duwamish River. The tide flats extended south beyond what is now Spokane Street and east to approximately Airport Way. Two to three main channels of the Duwamish River discharged through the tide flats toward the area where Harbor Island was constructed.

The tide flats were composed of fluvial sands and silts and were dissected with many braided drainage channels.

Work for the present configuration of Harbor Island began in 1903, when wooden containment cribs for fill material were constructed at the northern end of the proposed island. Construction proceeded in 1904 by filling the wooden containment cribs with dredge material from the West Waterway. The dredged material was slurried into the cribs and water was allowed to drain out through slats in the crib walls. Originally, 34 acres were filled at the north end of the island. Although data for the initial 34-acre fill district do not specify the actual size of individual filling cells, the average dimensions may have been about 700 feet by 1,000 feet based on the total linear footage of bulkheads noted in available records. Based on volumetric information in the annual progress report by the Chief Engineer, the fill was placed to an average depth of 16.25 feet. By 1906, about 140 acres had been filled, including the area which is now occupied by the Shell facilities. Work continued sporadically until about 1910 when the bulk of the island was complete.

The fill containment cribs were constructed by completing permanent outer and "temporary" inner bulkheads. The outside (perimeter) bulkheads were described as "brush" construction, using a combination of piles and horizontal logs to form a barrier. In some instances, riprap and boulders were placed to strengthen the bulkheads against tidal action. The "temporary" bulkheads consisted of driven pilings with lateral planks, and were placed "to protect the. . .boundaries of the fill from erosion, until adjoining districts are filled" (DNR Archive Record, 1904). The data on the initial 34-acre fill district at the north end of the island indicate that the permanent outer bulkheads were treated, but the "temporary" inner ones used untreated materials.

No mention regarding reuse of the "temporary" bulkhead materials is made in the construction reports from 1900 to 1904. The reported quantities of materials used, however, suggest that these structures were left in place after the filling process. Consequently, remnants of the plank and pile grid cells probably remain beneath the Harbor Island fill materials.

Historical Land Use

Early Industrial Development - 1890s to 1920s

By 1918, the East Waterway Dock and Warehouse Company was established east of 11th Avenue Southwest between Southwest Hanford and Southwest Lander Streets. The area is located immediately east of the present Shell terminal, on what is now Terminal 18, and land to the south. The area contained storage facilities and a bulking plant for vegetable and animal oils. "Chinese wood oil and poisonous oils" were also handled through the facility (East Waterway Dock and Warehouse Company, 1918). Oil-soaked cases and debris were burned in an incinerator and in open lots.

Other commercial activities on Harbor Island included commercial shipyards, boiler manufacturing, and varnish manufacturing along the East and West Waterways. These businesses are not expected to have affected the area currently occupied by Shell, due to their distance from the Shell terminal.

Industrial Development - 1920s to 1980

In general, the time period between 1920 and 1950 is characterized by the development of oil distribution and bulk storage plants (including Shell), metal manufacturing and recycling operations, and the expansion of the existing shipyard and commercial shipping terminals. Figure 2 shows the location of industries around the Shell terminal between 1924 and 1950. Table 2 is a key to those industries shown on Figure 2 and lists their approximate periods of operation.

Areas historically devoted to bulk storage plants, and metal manufacturing and recycling facilities, have a similar use today. Shipyard and container shipping operations continue along the East Waterway. Several small manufacturers and fabricators have been in operation southwest of the current Shell terminal on 13th Avenue Southwest since the early 1950s. Figure 3 shows the location of industries around the Shell terminal between 1950 and 1980. Table 3 is a key to those industries shown on Figure 3 and lists their approximate periods of operation.

Adjacent Petroleum Distribution Facilities

Terminal 18 Area. In 1924, Shell established a petroleum product distribution terminal on the East Waterway of the Duwamish River, east of the present Shell bulk fuel storage terminal (Figure 2, Facility Number 5). Additional land was acquired by Shell along the southern portion of the original property in 1939. The historical information sources reviewed did not specify the quantity or exact location of the additional land acquired. The site is now owned and operated by the Port of Seattle and occupies a portion of the Terminal 18 container shipping facility.

The former terminal included above-ground bulk storage tanks for a variety of petroleum products and asphalt, a garage, vehicle maintenance buildings, oil and grease warehouses, filling platforms, and a pipe shop. Subsurface pipelines were installed for product handling and transfer.

Shell operated the East Waterway distribution terminal until the property was acquired by the Port of Seattle for container shipping (Terminal 18) in about 1976. In 1980, the Port of Seattle demolished the former Shell structures during construction of the current container storage and transfer facility.

In 1980, the Port of Seattle installed several pipelines, extending from the current Shell facility, across Terminal 18, to the East Waterway dock area. These pipelines are currently in use. Fuel pipelines and related facilities have been maintained by the Port of Seattle since their installation.

The Port of Seattle continues to operate the Terminal 18 container storage and shipping facility east of the present Shell terminal. The Current Land Use map provided on Figure 4 shows the location of Port of Seattle operations as facility numbers 1 and 2. Current Terminal 18 activities include fuel transfer to and from barges and other vessels via above-ground and underground pipelines. Near the East Waterway, subsurface concrete vaults are used as product pipeline valve pits. Water which accumulates in the vaults is treated in oil/water separators and is then discharged to the East Waterway through the storm water system.

Other Adjacent Oil Companies. Other petroleum bulk storage and distribution terminals in the vicinity of the present Shell site were established by the General Petroleum Company in 1929, the Sunset Oil Company in 1938 (listed as Richfield Oil Company in 1948), and the Texas Oil Company in 1941. These facilities were located immediately north and immediately west of the present Shell terminal. Their respective locations are shown on Figure 2 as facility numbers 3, 4, and 9.

The General Petroleum tank farm, located northwest of the present Shell terminal, is currently operated by Texaco.

The former Sunset Oil tank farm, located immediately north of the present Shell terminal, continued operations under the Richfield Oil Company through the 1960s and ARCO through the 1980s.

The Texas Oil Company plant, located immediately west of the present Shell terminal, includes truck loading racks, a garage, valve pits, an oil and grease warehouse, and a drum reconditioning area. Bulk storage, fuel distribution, and related operations continue at this location under the name Texaco. Bulk storage tanks at the Texaco plant are enclosed within a concrete dike wall.

Currently, Shell leases part of the northern portion of its property to Olympic Pipeline Company for fuel distribution facilities. The facility is shown on Figure 4 as facility number 5. Fuels are transferred from the Olympic facility through the underground pipeline which travels south along 13th Avenue Southwest, east across the Shell A Yard, and then south along 11th Avenue Southwest. The Olympic Pipeline facility is unpaved.

Other current oil company operations in the vicinity of the present Shell terminal include Seaport Petroleum, a jobber for Texaco Petroleum, located on the west side of 13th Avenue Southwest. Lubricants and bulk fuels are stored in drums at this site. Its location is shown on Figure 4 as facility number 15.

Product Pipelines. Underground petroleum product lines from the Shell terminal and other adjacent bulk storage facilities are approximately located on Figure 5. Of particular note is the Olympic pipeline running south along 13th Avenue Southwest from the Olympic

Pipeline fuel delivery facility. The pipeline continues east across the northern portion of the Shell A Yard and continues south along 11th Avenue Southwest. The pipeline route was in place prior to 1938, as shown on a city utility map. The 1938 utility map coverage does not extend north of the present Shell D Yard, and the northern terminus of the pipeline at that time is uncertain.

Metal Processing, Manufacturing, and Recycling Facilities

Seafab Metals Corporation. Lead smelting and manufacturing has occurred since 1937 at the property located south of Southwest Lander Street and west of 13th Avenue Southwest (Figure 2, facility numbers 10 and 11). The property is located immediately west of the current Shell A Yard. The facility operated under several owners beginning with Northwest Lead in 1937. Lead smelting was discontinued at the site in 1984. Manufacturing operations, including metal casting and reduction, continue at the facility.

In 1949, Associated Lead and Zinc began lead oxide manufacturing immediately south of Northwest Lead then merged with Northwest Lead. In the 1950s, Bunker Hill acquired full ownership of the smelting and processing operations. The plant was sold to Gulf Resources and Chemical Company in 1968. Information regarding the fate and handling of facility wastes, including process wastewater and smelter/flue dust in the 1950s and 1960s was not available from the historical sources reviewed.

In 1969, Quemetco/Western Lead Products acquired the operation from Gulf Resources and continued operations into the 1980s (Figure 3, facility number 13). Quemetco processing operations utilized a bag house to recover dust from an air emission control system. Beginning in 1975, wastewater from plant operations (including battery recycling) was treated via pH adjustment with anhydrous ammonia, filtered with diatomaceous earth, and discharged into an open seepage lagoon at the southeast corner of the property. The wastewater was derived from battery acid, battery casing water, and storm water. The discharge of treated process water to the seepage lagoon at the site ceased in 1982.

In 1983, Bergsoe Metals Corporation acquired the property and in 1984 discontinued the lead smelter and refinery casting operation. Seafab Metals Corporation purchased the facility in 1984. At the time of the

Seafab purchase, waste piles of plastic battery casings and diatomaceous earth existed in concrete block cells. The smelter building was dismantled in 1985. The waste piles were removed and the seepage lagoon closed in 1987. Current Seafab operations are limited to lead fabrication, lead oxide production, and casting.

Seattle Iron and Metals. In about 1950, Seattle Iron and Metals established a scrap metal storage yard and metals recycling operation south of the present Shell A Yard (Figure 2, facility number 13). Nelson Iron Works also used land in this area for iron and scrap metal storage beginning in about 1946. Iron and steel handling and reduction at Seattle Iron and Metals included cutting by torches, mechanical shearing, and crushing.

Copper wire insulation was removed via an incinerator and ash was washed into an on-site settling reservoir. Washing ash from the incinerator into the settling reservoir was discontinued in 1986. Aluminum ash was also produced at Seattle Iron and Metals but was disposed of off site. Batteries were stored and sold on site, and electrical transformers were recycled on site until 1980. Individual inventory stockpile configurations in the yard area changed on a frequent basis, and portions of the working surfaces in the yard were graded and filled on several occasions. Scrap metal storage and recycling currently continues at the facility.

Leckenby Structural Steel Company. Leckenby Structural Steel Company began commercial steel fabrication in about 1946 immediately east of the current Shell A Yard area (Figure 2, facility number 8). The property was also used by Corrugated Sheeting Company for electrical equipment storage. The Leckenby facilities included parts manufacturing buildings and a paint shed near the western property boundary. Leckenby Steel continued its operation until Clough Industries acquired the property for truck tanker/container manufacturing in the 1980s.

Other Adjacent Metal Manufacturers. Prior to construction of the Shell loading terminal, Dimensional Engineering, a steel manufacturer, operated at the location of the current Shell A Yard in the 1970s (Figure 3, facility numbers 12 and 17). Specific details of the operation were not available.

Several other metal manufacturers and machine shops were established in the late 1940s to early 1950s on 13th Avenue Southwest, southwest of the current Shell A Yard (Figure 2, facility number 12). Manufacturing included stove, machine parts, tools, and equipment fabrication, which continued into the 1950s and 1960s. Manufacturers who continued operations through the 1980s included Pacific Wire Works, a wire-forming facility, and Non-Ferrous Metals, a scrap metal dealership (Figure 3, facility numbers 14, 15, and 16).

Until 1970, Non-Ferrous Metals operations included a smelter and refinery for scrap lead and zinc. The metal processing operations did not include a baghouse for flue dust. Since about 1972, Non-Ferrous Metals has operated solely as a scrap metal dealer. In 1986, Non-Ferrous Metals added a closed-loop cooling system because their waste stream contained hazardous substances (Ebasco 1990).

Other Commercial Activities

Furniture Manufacturing. A furniture manufacturing company and woodworking shop were present north of the current Shell terminal from about 1948 to 1950 (Figure 2, facility number 2).

Fiberglass Product Manufacturing. Starline Fiberglass and Chemical Wood Products, Inc. operated north of the former Richfield tank farm in the late 1950s (Figure 3, facility number 2).

Existing Shell Terminal

Tank Farm Areas. The present Shell terminal began development in 1944, with the construction of the B Yard tank farm (Figure 2, facility number 7). Construction included a concrete dike containment wall around the unpaved yard. Foamite fire suppressant storage structures were located in what is now the D Yard area, immediately north of the B Yard tank farm. A powerhouse was also present.

Underground fuel pipelines from the tank farm were connected to the existing Shell distribution terminal on the East Waterway. The approximate location of the underground pipelines across 11th Avenue Southwest is shown on Figure 5.

In 1951, Shell completed construction of the C Yard tank farm with a concrete dike containment wall (Figure 3, facility number 8). The B Yard and C Yard tank farm areas are presently unpaved. Locations of above-ground storage tanks in the Band C Yards are shown on Figure 4.

Currently, twenty one above-ground bulk fuel storage tanks exist in the B Yard and C Yard tank farm areas. Fuels include leaded and unleaded gasoline, diesel, jet fuels, and industrial and marine fuel oils. Fuels are primarily transferred between tanks via above-ground piping and are loaded to and from barges and other vessels at Terminal 18 via underground piping running beneath 11th Avenue Southwest. Fuels are also piped underground to the A Yard tanker truck loading racks as shown on Figure 5.

Sixteen documented releases of petroleum hydrocarbon product have occurred at the Shell facility since 1965 (Table 4). Losses have resulted from tank overfills, broken filters, and valve and line failures.

Tank Farm Utilities and Underground Storage Tanks. A runoff drainage system was installed by Shell in the B and C Yards in the 1950s. Figure 5 shows the approximate configuration of the former tank farm yard drainage system. Runoff was collected near the northeast corner of the B Yard and southeast corner of the C Yard. The yard drainage system included an oil/water separator at each yard collection area. Collected runoff was discharged to earthen sump areas in the D Yard (B Pit and C Pit), and then into the 11th Avenue Southwest storm sewer via underground concrete piping. The C Yard drainage system was subsequently rerouted to an oil/water separator and slop tank at the west side of the D Yard. Water discharged through the separator flowed into the 13th Avenue Southwest storm sewer. In 1992, the C Yard drainage system was decommissioned, and the D Yard separator was abandoned in place. It was not possible to remove the D Yard separator because of its proximity to power supply conduits.

The B Yard drainage system, oil/water separator, and associated piping were removed in the 1970s. The C Yard drainage system, oil/water separator, and slop tank were also abandoned. The collection area at the southeast corner of the C Yard was filled with soil in about 1988.

In about 1980, underground PVC lines were installed in the B and C Yards for discharging tank bottom water to the oil/water separator and slop tank at the west end of the D Yard. These lines were abandoned in place in the mid-1980s. The abandoned PVC lines are approximately located on Figure 5. Tank bottom water is currently collected by vacuum trucks and is disposed of off-site as necessary.

A 1,000-gallon underground storage tank for glycol antifreeze product additive was removed from the D Yard by Shell in about 1987. The additive was injected directly into above-ground product fuel lines.

Loading racks in the E Yard were equipped with overfill and spill protection, and an underground storage tank for loading rack fuel slop and contact water. The rack was abandoned in 1992, and the underground piping and slop tank were removed.

A Yard Fuel Loading Racks. In 1979-1980 Shell constructed the A Yard tanker truck terminal. Shell leases the A Yard property from the Port of Seattle. Fuels from the B Yard and C Yard tank farms are supplied to two fuel loading racks in the A Yard. Gasoline, diesel, kerosene, and jet fuel are distributed at a loading rack near the north-central portion of the yard, and heavier grade fuel oils ("black oil") are distributed at a separate loading rack near the northern boundary of the yard. During construction of the A Yard, the loading racks were equipped with overfill protection and pavement collection grates for contact water and product slop.

A Yard Underground Storage Tanks. One underground storage tank (UST) for furnace fuel for the Shell Terminal office building, and four underground fuel/contact water slop tanks were installed during A Yard construction. The tanks have a capacity of 2,000 to 10,000 gallons. The diesel UST in the southern portion of the A Yard was removed by Shell in 1988. The heating fuel tank was removed in 1991, and the furnace was converted to natural gas service. The oil/water separator associated with the slop tanks was removed in 1992, and the runoff and contact water from the central loading rack is piped directly to the slop tanks. The "black oil" rack has not been in service since approximately 1988. Approximate locations and configurations of the fuel USTs, underground slop tanks, and piping are shown on Figure 5. The A Yard was completed with a cover of asphalt pavement to a minimum thickness of about nine inches, following installation of the underground tanks.

The A Yard slop tanks hold distillate from the on-site Shell laboratory, product slop and contact water from the load racks, and waste lubrication fluids from the plant maintenance garage. The slop tanks are connected to the loading racks and the other facilities listed via underground piping. Slop tank contents are periodically pumped out and transported via truck tanker for reprocessing at the Shell refinery in Anacortes, Washington. Parking lot runoff from the A Yard is routed to the storm drain system on 13th Avenue Southwest.

Fuel Additives and Other Hazardous Substances. Detergent and polyglycol fuel additives are mixed and added to fuels by Shell on the site. The additives are typically injected directly into product fuel lines. These additives do not include lead-based compounds.

Other hazardous substances handled by Shell include storage tank bottom sludge and used gasoline filters. The fire suppression system includes a synthetic fluorinated foam which contains toxic substances; however, the foam has never been used at the site.

Hazardous materials are stored in the D Yard on a bermed concrete containment pad. Minor spills or leaks from drums and other containers in the containment area are cleaned up immediately. Hazardous wastes have been removed from the Shell terminal for off-site disposal by a waste disposal contractor since at least 1965.

LOCAL FEATURES AND SUBSURFACE CONDITIONS

This section describes the location of the Shell terminal relative to adjacent properties and area features, and summarizes subsurface soil and hydrogeologic conditions in the area.

Location and Description of Existing Shell Terminal

The Shell Harbor Island bulk fuel storage terminal is located in the north-central portion of Harbor Island in Seattle, Washington, as shown on Figure 1. An aerial photograph showing the facility and current land uses adjacent to the facility is provided on Figure 4.

The terminal is bordered on the west (across 11th Ave. SW) by the Port of Seattle's Terminal 18, immediately to the north by the ARCO bulk storage facility, on the east (across 13th Ave. SW) by the Texaco bulk storage facility, to the southwest (across 13th Ave. SW, south of SW Lander St.) by Seafab Metals Corp. and Pacific Wire Works, and immediately to the south by Clough Industries.

The Shell terminal is composed of six distinct land use areas: the A, B, C, D, and E Yards, and one parcel of land leased to the Olympic Pipeline Company, as shown on Figure 4.

The A Yard is the southern-most area and is used primarily for tanker truck loading operations. The A Yard is not specifically part of this investigation. The A Yard houses two fuel loading racks, a maintenance building, and the Shell terminal office building. The area is entirely paved, relatively level, and bounded by the B Yard containment dike to the north and a chain-link fence in other directions.

The B Yard is located immediately north of the A Yard and is used as a bulk fuel storage area. The B Yard is surrounded by a concrete containment dike, is unpaved, and relatively level. The B Yard houses 15 large above-ground fuel storage tanks. The B Yard may be entered from the A Yard via a walkway or from the D Yard via a driveway.

The C Yard is located immediately north of the D Yard and is used as a bulk fuel storage area. The C Yard is surrounded by a concrete containment dike, is unpaved, and relatively level. The C Yard houses six large above-ground fuel storage tanks. The C Yard may be entered from the D Yard via two walkways or from the E Yard via a driveway.

The D Yard is located immediately north of the B Yard and is primarily used as the terminal maintenance area. The D Yard is bounded to the north and south by the C and B Yard containment dikes, and to the east and west by chain-link fences. Entry gates are located to the east and west. The yard contains numerous maintenance buildings, several material handling and storage areas, and a variety of above-ground and underground product utility lines. The yard is relatively flat and partially paved.

The E Yard is located in the northeast corner of the Shell property. The area formerly served as a fuel loading rack facility. It is bounded to the north and south by the ARCO bulk fuel storage terminal and the C Yard containment dikes. Entry is gained through a gate in a fence to the east. The Olympic Pipeline facility is located to the west. The area is largely unpaved. The site is currently leased to Chevron for empty tanker truck parking.

The Olympic Pipeline Pumping Station is located in the northwest corner of the Shell property. The Olympic Pipeline pumping station is located on this property. It is bounded to the north and south by the ARCO bulk fuel storage facility and the C Yard containment dikes. Entry is gained through a gate in a fence to the west. The E Yard facility is located to the east. The area is largely unpaved.

Regional Hydrogeologic Setting

Summary of Soil and Hydrogeologic Conditions

- Two primary soil units underlie Harbor Island: fill, about 15 feet thick, principally composed of hydraulically placed fine to medium sand; and underlying native sediments composed of silty sand with silt interbeds.
- Groundwater beneath the island appears stratified with a shallow unconfined lens of fresh water found in the fill and shallow native sediments, and a deeper brackish zone within the native sediments.
- Shallow groundwater is mounded near the center of the island and predominantly flows radially outward toward the East and West Waterways and Elliott Bay.
- Ocean tides produce groundwater level fluctuations along the edge of the island which may affect local groundwater gradients and flow directions. These effects diminish inland and are probably minimal near the center of the island.

Sources of Hydrogeologic Information

The hydrogeology of Harbor Island has been explored by a number of investigators. Ebasco (1990) recently finalized its Phase I Remedial Investigation Report of Harbor Island for the EPA. This report provided most of the regional or island-wide hydrogeologic information presented herein. In addition, several hydrogeologic investigations on properties surrounding the Shell bulk terminal were used. The properties and investigators include:

- ARCO's fuel terminal to the north (Engineering Enterprises, 1987);
- Port of Seattle's Terminal 18 to the east (GeoEngineers, 1988);
- Seattle Iron and Metals Corporation to the south (Roy F. Weston, 1988);
- Seafab Metals Corporation to the southwest (Battelle, 1989); and
- Texaco's fuel terminal to the northwest (Groundwater Technology, 1985 and 1986).

Regional Stratigraphy

Harbor Island is a man-made island constructed at the mouth of the Duwamish River. In general, the upper 5 to 15 feet of the island is hydraulic fill dredged from the surrounding river delta capped with shore-placed fill. Soil units beneath the island are described in greater detail below. Refer to Figure 6 for a graphic representation of the soil and hydrogeologic conditions.

Fill. The uppermost layer across Harbor Island is a shore-placed sandy gravel and cobble aggregate. The unit ranges from one to six feet in thickness. The aggregate fill is characteristically a medium dense, dark brown, silty, sandy gravel with cobbles and occasional ceramic tile, asphalt, metal, and wood chips.

Hydraulically placed dredge spoils underlie the aggregate layer and overlie native sediments across Harbor Island. The fill is approximately 5 to 15 feet thick across the island and predominantly consists of medium dense, black to dark reddish or grayish brown, fine to coarse sand, interbedded with thin (0.1 to 0.5 foot) silty sand, silt, and clay layers. The clay layers are typically medium stiff to stiff, dark brown to dark gray, silty clay. The composition of the fill material closely resembles the original underlying river delta sediments. The hydraulic spreading process may be responsible for stratification within the fill deposit.

Native Sediments. The underlying native sediments were deposited in the intertidal portion of the Duwamish River delta. The sediments consist of loose sand interbedded with silt and thin clay layers. Shell fragments and wood chips are common. Bedding is nearly horizontal.

Surface Water

Harbor Island is bounded on the east and west by the East and West Waterways, on the north by Elliott Bay, and on the south by the mouth of the Duwamish River. The salinity of Elliott Bay is approximately 28 parts per thousand (ppt), and the salinity of the diluted salt water wedge which intrudes the East and West Waterways and the Duwamish estuary is approximately 25 ppt (Pyrch et al., 1975). The waterway bottoms are roughly 30 to 60 feet below mean lower low water (NOAA, 1984). Average diurnal tidal fluctuations in Elliott Bay are approximately six feet (NOAA, 1984).

Hydrogeologic Units

The shallow groundwater system beneath Harbor Island includes a thin unsaturated zone within the fill horizon and a saturated zone within both the fill and underlying native sediments. The system is apparently stratified with fresh water near the surface and slightly brackish water at a depth of approximately 65 feet. The shallow groundwater system is apparently recharged by precipitation which infiltrates the unpaved portions of the island, producing a shallow lens of fresh groundwater.

Fresh groundwater is typically encountered at depths of between 5 and 10 feet below the ground surface under generally unconfined conditions (Ebasco, 1990). The slightly brackish water found in three deep EPA wells suggests that saline and fresh water are mixing beneath the island. This may be due to the intrusion of saline water from Elliott Bay and the surrounding waterways beneath the site or may simply reflect the existence of a fresh water lens perched within a saline or brackish water aquifer (Ebasco, 1990).

Regional Groundwater Gradients

Hydraulic Gradients. Figure 7 is a groundwater elevation contour map for shallow monitoring well data collected in September 1989 (after Ebasco, 1990). Groundwater is typically encountered at depths of 5 to

10 feet below the ground surface, or 1 to 5 feet above mean sea level in the shallow groundwater system. Island-wide groundwater level measurements in February, March, and September 1989 (Ebasco, 1990) displayed relatively consistent results -- higher groundwater elevations are typically observed in the north central half of the island and a relatively depressed zone extends from the southeastern quarter of the island toward the center. Ebasco (1990) reports regional horizontal hydraulic gradients ranging from 0.0005 to 0.009 (assuming the time-averaged water table elevation is zero at the island perimeter).

Hart Crowser compiled available historical groundwater elevation data for several Harbor Island sites, including Seafab Metals (Battelle, 1989), ARCO (Engineering Enterprises, 1987), Terminal 18 (GeoEngineers, 1988), and Seattle Iron and Metals (Roy F. Weston, 1988).

Our interpretation of groundwater elevations at these sites is presented on Figure 8. This analysis is approximate because in many cases different datums were used to reference groundwater elevations and the data were collected at different times. As shown on Figure 8, generally eastward groundwater gradients were observed on the east side of Harbor Island, generally westward gradients were seen on the west side of the island, and generally southerly or southwesterly gradients were observed in the south central portion of the island.

Tidal Effects. Figure 9 shows interpreted contours of equal tidal fluctuation across Harbor Island based on data collected in 1990 (Ebasco, 1990). Tidal fluctuations in the adjacent waterways appear to influence many of the monitoring wells on Harbor Island to some degree. Tidal fluctuations may lead to groundwater gradient reversals near the perimeter of the island and may complicate evaluation of seasonal changes in site water levels.

Diurnal groundwater level fluctuations range from 0.01 to 0.9 foot across the island (Ebasco, 1990). In general, shallow monitoring wells close to the island perimeter exhibit the greatest fluctuations. Tidal influences are retarded from 1 to 5 hours as fluctuations travel inland.

Hydrologic Parameters

Ebasco (1990) conducted slug tests in 17 shallow monitoring wells across Harbor Island. They reported hydraulic conductivities ranging from 9×10^{-4} to 2×10^{-2} cm/sec.

Regional Groundwater Flow

The unconfined groundwater system beneath Harbor Island appears to be principally recharged by precipitation infiltration. Based on the higher groundwater elevations observed in these areas, the primary recharge areas appear to be near the Shell, ARCO, and Texaco bulk terminals. The observed groundwater gradients project radially outward from the north central part of the island, suggesting lateral groundwater flow with discharge at the perimeter of the island.

Shell Terminal Hydrogeologic Conditions

Sources of Hydrogeologic Information

The Shell terminal is located near the center of Harbor Island. In general, the hydrogeologic conditions found at the bulk terminal are consistent with the regional system described above. Groundwater monitoring well installation and basic hydrogeologic investigation at the Shell bulk terminal began in 1973. Several well installation and abandonment phases have occurred since that time. Three reports produced by Law Engineering (1988, 1989, and 1990) provide the most detailed hydrogeologic characterization of the site to date and are the primary sources of the site-specific hydrogeologic information provided herein. In addition to these reports, groundwater level and groundwater quality data were collected by Hart Crowser (1990a, 1990b, and 1992). These data are also incorporated into this discussion.

Groundwater Monitoring Wells

Fifty-six groundwater monitoring wells, including one well (EPA-11) installed by Ebasco under contract to the EPA, currently exist at or immediately adjacent to the Shell bulk terminal facility. Twenty-six of these wells are located within the B, C, D, and E Yards, as shown on Figure 10, and are the primary focus of this discussion.

In general, monitoring wells 1 through 27 were installed to delineate free-phase hydrocarbon plumes within the tank farm areas and were screened from the ground surface to approximately 25 feet in depth. The A Yard wells were installed at various depths to monitor water quality conditions downgradient from several underground storage tanks.

Site Stratigraphy

The subsurface conditions encountered beneath the Shell facility are similar to those previously described for Harbor Island in general. Approximately one to five feet of gravelly sand aggregate fill overlies dark gray to black, slightly silty, sandy, dredge fill. Some borings encountered sandy silt and silty clay layers between 12 to 20 feet below the ground surface, possibly indicating contact with the underlying native sediments. Appendix A includes boring logs from the A Yard (Boring logs A-1 to A-5, and A-15 are not available). Boring logs were not completed for wells completed in the tank farm areas.

Surface Water

No surface water bodies are located on the Shell property. The terminal is located approximately 900 feet from the East Waterway and 1,400 feet from the West Waterway.

Site Hydrogeologic Units

Available data suggest that both the lateral and vertical extent of the shallow groundwater system below the Shell terminal may be limited by the presence of saline or brackish water at depth. Brackish groundwater has not been observed in studies conducted at the Shell terminal. However, Ebasco (1990) encountered the deeper brackish groundwater in three monitoring wells drilled to depths of 65 feet within 1,200 feet of the site.

Site Groundwater Gradients

Hydraulic Gradients. Hart Crowser measured groundwater levels in the on-site monitoring wells on May 14, 1992. Depths to groundwater ranged from about four feet below ground surface at the north end of the site, to about eight feet on the south end of the site. A groundwater elevation contour map is presented on Figure 11, with depths to groundwater and respective water level elevation data summarized in Table 5.

The groundwater elevation contour map shows what appears to be one quarter of a gently mounded groundwater surface to the northwest (C and D Yards) and a relatively flat groundwater table to the south (A Yard). Groundwater generally appears to flow to the south across most of the site. However, the apparent mounding in the C and D Yards may produce local flow toward the eastern property boundary. These groundwater flow patterns are similar to those reported by Law Engineering in 1988 and 1989, and are consistent with the island-wide groundwater elevation contour map shown on Figure 7.

Tidal Effects. Data obtained by Ebasco (1990) suggest that tidal fluctuations may be less than 0.1 foot in most on-site monitoring wells.

Site Hydrologic Parameters

Slug tests conducted in Harbor Island monitoring wells by Ebasco (1990) included several wells on or adjacent to the Shell terminal. Estimated hydraulic conductivity values near the Shell terminal ranged from 2×10^{-3} cm/sec to 9×10^{-3} cm/sec.

Law Engineering (1990) conducted a 24-hour, variable rate pumping test on monitoring well A-10 in February 1990. Their calculated transmissivity values ranged from 12,120 to 22,940 gal/day/ft with storage coefficients ranging from 0.03 to 0.14.

Site Groundwater Flow

Law Engineering (1989) estimated a local (southerly) horizontal groundwater flow rate equal to 64 ft/yr, assuming an average hydraulic conductivity equal to 35 ft/day, an average horizontal hydraulic gradient equal to 0.002, and a porosity of 0.15.

PREVIOUS ENVIRONMENTAL ASSESSMENTS

This section summarizes previous subsurface investigations conducted at and in the vicinity of the site, including the results from previous sampling events, focusing on physical and chemical characteristics, identified compounds, and other pertinent information.

Soil and Groundwater Quality at the Shell Terminal

Information for the soil and groundwater summary came from the following investigations:

- Free Product Delineation - A Yard and Vicinity (Hart Crowser, 1992);
- Groundwater and Free Product Level Monitoring (Hart Crowser, 1990b);
- Phase I Remedial Investigation (RI) of Harbor Island (Ebasco, 1990);
- Monitoring Well Installation and Modifications (Law Engineering, 1989); and
- Report of Site Hydrogeological Assessment (Law Engineering, 1988).

Information in the following subsections includes a summary of monitoring well installation work completed by various investigators, and summaries of soil quality, groundwater quality, and free petroleum product occurrence data. Table 5 summarizes monitoring well information.

Observation Well Installations - Shell Oil Company. In 1973 and 1981, Shell installed a total of 49 wells in the B, C, and D Yards to observe the distribution of floating product near historical spill areas. The wells were subsequently removed. In 1984 Shell installed the existing network of 26 observation wells in the tank farm areas. The wells were installed via water jetting, with well screens extending to or above the ground surface. Six other wells installed by Shell in 1985 and 1986 included five wells (A-1 through A-5) in the A Yard. Well locations are shown on Figure 10.

Monitoring Well Installations - Law Engineering. Under contract to Shell, Law Engineering installed nine groundwater monitoring wells (A-6 through A-14) in January and April of 1989 in the A Yard. The Law wells were installed to delineate the extent of floating product in the A Yard and to monitor groundwater quality downgradient from several underground fuel storage and slop tanks. Following Shell's removal of a diesel UST from the southern end of the A Yard, Law installed well A-15 in the tank excavation backfill to facilitate product recovery and groundwater monitoring.

Law also modified the previously existing A Yard wells (A-1 through A-4) by installing bentonite and concrete surface seals. For the existing Shell wells in the B, C, and D Yards, Law removed the upper 2 to 3 foot sections of well screen that extended above the ground surface, replaced them with solid casing sections, and installed concrete surface seals and monuments.

Law Engineering identified floating product in several A Yard wells near the heavy oil loading rack and the office slop tank areas. The results of product samples collected and analyzed from wells A-3, A-4, A-6, A-7, and A-9 suggest the petroleum hydrocarbons were primarily weathered leaded gasoline. Law attributed the presence of the product to a 1982 release of 9,400 gallons of leaded gasoline from storage tank number 35 in the C Yard. Law also identified floating diesel product in wells A-10 and A-15 near the former diesel UST at the southern end of the A Yard. Free product was also detected in a few of the B Yard wells. Chemical screening results indicated that the petroleum hydrocarbons were primarily kerosene or gasoline.

Shell has historically recovered floating product from the A Yard wells by hand bailing and skimming. Hart Crowser currently operates two product recovery skimmer pumps that are alternated between wells in the vicinity of A-6 and A-9.

Hart Crowser Activities. Hart Crowser began site investigation work for the Shell Harbor Island terminal in April 1990. Hart Crowser work has included the following:

- Collecting groundwater samples from the existing tank farm observation wells and performing preliminary screening analyses for fuel compounds; and

- Installing 14 groundwater monitoring wells in the A Yard and vicinity to characterize the extent of free product plumes in the area; and

- Obtaining fluid elevation measurements in site wells to determine groundwater flow directions and floating product thicknesses.

Soil Quality Findings

EPA Borings. Elevated concentrations of total lead (up to 1,310 mg/kg) were detected in soil samples collected from EPA borings MW-07 and MW-11 (Ebasco, 1990). Boring MW-07 is located off-site, immediately east of the tank farm area, and boring MW-11 is located on-site in the northeast corner of the A Yard (Figure 12). Low levels of PAHs were also detected in surface soils collected from both borings. Volatile organics, pesticides, and PCBs were not detected in the soil samples. Soil samples were analyzed for target compound list (TCL) parameters.

Hart Crowser Investigations. Total petroleum hydrocarbon (TPH) and benzene, ethylbenzene, toluene, and total xylenes (BETX) soil testing results from three phases of monitoring well installation work completed by Hart Crowser in the A Yard and vicinity are summarized in Table 6 (Hart Crowser, 1992). TPH and BETX were not detected in soil samples collected from monitoring wells A-16 through A-18, A-21, and A-24. Soil samples from monitoring wells A-19, A-20, A-22, A-23, and A-25 through A-29 showed elevated concentrations of TPH and BETX.

In addition, several soil samples were analyzed for PCBs and toxicity characteristic leaching procedure (TCLP) lead and/or metals to characterize soils for disposal. TCLP lead was detected in soil samples from A-18, A-20, A-21, and A-22 at concentrations of 0.5, 1.7, 0.6, and 1.1 mg/L, respectively. TCLP lead was below detection limits in all other samples.

Groundwater Quality Findings

Total Organic Carbon and Conductivity Analyses. Law Engineers (1988) collected water samples from wells located in A, B, C, and D Yards and analyzed them for total organic carbon (TOC) and conductivity. TOC concentrations ranged from 3.5 mg/L in well 27 to 230 mg/L in well 25. Conductivity ranged from 62 μmhos/cm in well 26 to 4,000 μmhos/cm in well A-3.

EPA Monitoring Wells. Petroleum odors were reported while drilling EPA monitoring wells MW-07 and MW-11 (Ebasco, 1990). MW-07 is located along the eastern margin of tank farms and MW-11 (EPA-11) is located in the northeast corner of the A Yard as shown on Figure 12. Low concentrations of ethylbenzene (19 μg/L) and total xylenes (67 μg/L) were detected in MW-07. Low concentrations of total xylenes (5 μg/L) and acetone (44 μg/L) were detected in MW-11.

TPH and BETX groundwater testing results from three phases of monitoring well installation work completed by Hart Crowser in the A Yard and vicinity are summarized in Table 7 (Hart Crowser, 1992). In general, the highest concentrations of BETX were detected in monitoring well A-19, medium concentrations of BETX were detected in A-16, A-17, and A-23, and little or no BETX was detected in A-18, A-21, and A-24. These results are consistent with the free product delineation findings presented in the next section and indicate BETX affected groundwater is principally located beneath and in the immediate vicinity of free product areas. No groundwater samples were collected from wells where free product was present.

Free Petroleum Product Findings. Free petroleum product was found on the surface of the water table in several areas within the A Yard and in the southwest corner of the B Yard on May 14, 1992 (Hart Crowser, 1992). These wells are shown on Figure 11. In addition, a summary of free product thicknesses detected in wells on this date and a summary of those wells where free product has been detected in the past is presented in Table 5.

Soil and Groundwater Quality on Adjacent Properties

The adjacent facilities discussed in this section include the ARCO bulk terminal, Port of Seattle - Terminal 18, Seattle Iron and Metals, Seafab

Metal Corporation, and the Texaco bulk terminal. The information summarized includes soil and groundwater quality data.

ARCO North Yard

The results of EPA's Remedial Investigation of Harbor Island and Engineering Enterprises Inc., (EEI) investigation of the ARCO bulk storage terminal north of the Shell terminal indicate petroleum hydrocarbons in soils and groundwater on the property.

In 1988 and 1989 as part of EPA's Remedial Investigation, subsurface soil samples were collected from one boring (EPA BH-03) located just east (downgradient) of the ARCO storage facility (Ebasco, 1990). The boring was converted into a monitoring well (EPA MW-03) that screens the shallow groundwater zone from 5.5 feet to 15.5 feet below grade. In 1987, EEI drilled six borings (B-10 through B-15) and installed one groundwater monitoring well (MW-5) at the ARCO facility as part of a limited subsurface environmental assessment (EEI, 1987). This monitoring well was also screened in the shallow groundwater zone (between depths of 3 feet and 13 feet). The approximate location of these explorations is shown on Figure 12.

Soil Quality Findings. Lead concentrations up to 232 mg/kg were detected in surface to near-surface fill material (surface to 3 feet depth) in boring EPA BH-03 (Ebasco, 1990). Ethylbenzene (14 μg/kg), total xylenes (27 μg/kg), and trichloroethene (29 μg/kg) were also detected in the soil samples. Semivolatile organics, PCBs, and pesticides were not detected in the soil samples. Soil samples were analyzed for TCL parameters.

Petroleum-stained soils and free petroleum hydrocarbons on the surface of the water table were observed in all the borings drilled by EEI (1987). Soil samples were collected but not chemically analyzed during the EEI site assessment.

Groundwater Quality Findings. Common components of petroleum products such as ethylbenzene (6 μg/L), toluene (1 μg/L), and 2-methylnaphthalene (8 μg/L) were detected in the groundwater sample collected from EPA MW-03 (Ebasco, 1990). In addition, unfiltered (total) arsenic (4.20 μg/L), lead (10.90 μg/L), mercury (0.40 μg/L), and other metals were detected in the groundwater. One groundwater sample was collected from EPA MW-03 and analyzed for TCL parameters.

A trace (< 1 inch) of free product was observed in monitoring well MW-05 (EEI, 1987). However, groundwater was not chemically analyzed during EEI's investigation.

Terminal 18

The results of monitoring efforts conducted during EPA's Remedial Investigation and by the Port of Seattle have indicated the presence of petroleum compounds in soils and groundwater over much of the property.

Thirteen monitoring wells (MW-1 through MW-13) were installed on the Terminal 18 property as part of the Port of Seattle's subsurface study (GeoEngineers, 1988). GeoEngineers completed the subsurface explorations, sampling, and analyses at the site during 1987 and 1988.

During 1989, one soil boring (EPA BH-13) was installed and converted to a monitoring well (EPA MW-13) on the Port of Seattle- Terminal 18 property as part of EPA's investigation (Ebasco, 1990). Monitoring wells from both investigations were screened in the shallow water-bearing zone (between depths of 4.5 and 20.5 feet) and are approximately located on Figure 12.

Soil Quality Findings. Although soil samples were not chemically analyzed during GeoEngineer's site investigation, petroleum odors and sheens were observed in soil samples collected from most borings (GeoEngineers, 1988). Hydrocarbon (combustible) vapors were also detected at elevated concentrations (> 400 parts per million) within the well casings of nine of thirteen monitoring wells using a photoionization detector.

Chemical parameters of concern were not detected in soil samples collected during EPA's investigation (Ebasco, 1990). Several soil samples were collected from boring EPA BH-13 and analyzed for TCL parameters.

In addition, petroleum compounds were encountered in soil borings during a previous geotechnical study (Twelker & Associates, 1973), during a corrosion control study (Norton Corrosion Limited, 1986), and during demolition of the bulk storage terminal in 1980.

Free Petroleum Product Findings. GeoEngineers (1988) detected free (floating) product in five of the thirteen groundwater monitoring wells installed on the property. The product plume extended over the central and southeastern portions of the property near the bulkhead in the middle section of Terminal 18. The thickness of free product measured in these wells varied seasonally, ranging from 0 to 1.56 feet. Chemical analysis of product samples indicated that the product consisted of a mixture of gasoline and diesel fuels. Ebasco did not observe free petroleum product in monitoring well EPA MW-13.

Groundwater Quality Findings. Petroleum hydrocarbons, BETX, dissolved organic lead, and total dissolved lead were detected in groundwater during the GeoEngineers investigation (GeoEngineers, 1988). BETX and lead are common components of petroleum products (e.g., gasoline). Elevated petroleum hydrocarbons (20.3 to 62 mg/L), benzene (35 to 2,500 μg/L), and xylene (31 to 423 μg/L) concentrations were detected in groundwater samples collected from monitoring wells in the central portion of the property. Dissolved organic lead (4 μg/L) and total dissolved lead (50 μg/L) were detected in one monitoring well (MW-1) located near the western property line. Groundwater samples were analyzed for aromatic volatile organics, petroleum hydrocarbons, dissolved organic lead, and total lead.

One groundwater sample was collected from EPA MW-13 and analyzed for TCL parameters. Chemical parameters of concern were not detected in monitoring well EPA MW-13 installed during EPA's investigation (Ebasco, 1990).

Seattle Iron and Metals Corporation

The EPA and the Roy F. Weston investigations at the Seattle Iron and Metals Corporation property have shown heavy metal and PCB compounds in surface and near-surface soils (up to 4 feet below grade), and petroleum compounds in surface soils in some areas (Ebasco, 1990).

In 1988 and 1989, as part of their Remedial Investigation of Harbor Island, the EPA collected twenty-one surface or near-surface soil samples, and drilled six soil borings (EPA BH-P1, EPA BH-S1 through EPA BH-S3, EPA BH-12, EPA BH-15, and EPA BH-16) on or near the Seattle Iron and Metals property. Three of the borings were converted to monitoring wells—two shallow wells (EPA MW-12 and EPA MW-15, screened from approximately 10 feet to 20 feet below grade) and one deep well (EPA MW-16, screened from 55 feet to 65 feet below grade).

In addition, Weston collected over 140 surface or near-surface soil samples and drilled four borings that were converted to monitoring wells as part of an EPA Consent Order (No. 1081-01-21-2615) requiring Seattle Iron and Metals Corporation to conduct sampling at their facility (Weston, 1988). Weston completed the surface and subsurface explorations, sampling, and analyses at the site from June to September 1988. The monitoring wells were screened in the shallow groundwater zone (between 7 feet and 18.5 feet below grade).

Soil Quality Findings. The Seattle Iron and Metals main yard was, based on the concentrations of most chemicals of concern, the most affected area investigated during EPA's Remedial Investigation (Ebasco, 1990). Elevated concentrations of most metals (e.g., lead at 15,600 mg/kg, mercury at 23 mg/kg), volatile organics (e.g., tetrachloroethene at 2.5 mg/kg), low molecular weight polynuclear aromatic hydrocarbons (LPAHs), high molecular weight polynuclear aromatic hydrocarbons (HPAHs), and PCBs (420 mg/kg) were detected in surface and near-surface soils. Pesticides were not detected in the soil samples. Discrete and composite surface and subsurface soil samples were collected on the Seattle Iron and Metals property and were analyzed for TCL parameters.

Based on results of Weston's environmental assessment of the Seattle Iron and Metals property, surface soils containing PCB concentrations greater than 50 mg/kg cover an area of approximately 27,000 ft^2 (Weston, 1988). They estimated the volume of affected soil (PCBs > 50 mg/kg) to be 506 yd^3. PCBs concentrations in surface soil samples ranged from below the detection limit to 6,397 mg/kg (mean = 135 mg/kg). Elevated concentrations of PCBs were also detected in subsurface soils to a depth of approximately 4 feet below grade. Surface and subsurface soil samples collected during the Weston site investigation were analyzed for PCBs only.

Groundwater Quality Findings. Elevated concentrations of some metals (e.g., dissolved arsenic [16.30 μg/L], dissolved cadmium [19.80 μg/L], dissolved chromium [11.90 μg/L], total chromium [137 μg/L], and total lead [411 μg/L]), acetone (15 μg/L), benzene (52 μg/L), chloroethane (28 μg/L), and LPAHs (e.g., naphthalene [39 μg/L]) were detected in the groundwater on or near the Seattle Iron and Metals property during EPA's investigation (Ebasco, 1990). No other volatile organic compounds, semivolatile organics, pesticides, nor PCBs were detected in the groundwater. In general, metals and organic compounds were detected at lower concentrations in the deeper well (MW-16). However, MW-16 was the only deep well with detectable organics during EPA's investigation. Groundwater samples were collected from EPA MW-12, EPA MW-15, and EPA MW-16, and were analyzed for TCL parameters.

PCBs were not detected in the groundwater during the Weston site investigation (Weston, 1988). Groundwater samples were collected from MW-01 through MW-04 and were analyzed for PCBs only.

Seafab Metals Corporation

The results of EPA's Remedial Investigation, Battelle's RCRA 3013 Assessment, and Hart Crowser's site investigation of Seafab Metals Corporation have indicated the presence of soils and groundwater containing elevated concentrations of some metals (e.g., lead and cadmium).

In 1988 and 1989 as part of EPA's investigation of Harbor Island, two soil borings (EPA MW-09 and EPA BH-10) were installed just south of and generally downgradient of the Seafab Metals property (Ebasco, 1990). The borings were converted to monitoring wells—one shallow well (EPA BH-09, screened from a depth of 5 to 12 feet) and one deep well (EPA MW-10, screened from a depth of 55 to 65 feet).

In addition, Battelle collected soil and groundwater samples from eleven soil borings and twenty-six monitoring wells in response to an EPA Consent Decree (Battelle, 1989). Battelle completed the subsurface explorations, sampling, and analyses at the site from January 1989 to March 1989. Fifteen monitoring wells were screened at depths between 5 and 15 feet. The remaining eleven monitoring wells were screened at depths between 10 and 35 feet.

In 1985 and 1986, Hart Crowser drilled six borings and installed seven monitoring wells near the water treatment building and former seepage lagoon at the southeast corner of the property. The monitoring wells were screened at depths between 6 and 43 feet.

Soil Quality Findings. Ebasco (1990) detected elevated arsenic (129 mg/kg) and lead (22,700 mg/kg) concentrations in surface soils collected from boring EPA BH-09. Semivolatile organics, pesticides, and PCBs were not detected in the soil samples. Soil samples were analyzed for TCL parameters except for volatile organics.

Battelle (1989) detected elevated lead (44,000 mg/kg) and cadmium (69 mg/kg) concentrations in soil samples collected from several borings located in the southeastern portion of the property. Some of these soils exhibit concentrations of extractable lead and cadmium exceeding the extraction procedure toxicity (EP Tox) standard for dangerous waste under Chapter 173-303 WAC. The extent of affected soils in this area, based on the chemical results for lead and cadmium, is approximately 50,000 ft^2. Adjoining the former seepage lagoon, compounds of concern may persist in the soil to a depth of 20 feet below grade. Soil samples were collected from each of the 37 borings and analyzed for total lead and cadmium, EP Tox lead and cadmium, and sulfate.

Hart Crowser (1986 and 1987) collected soil samples to evaluate physical soil conditions, and did no soil chemical testing.

Groundwater Quality Findings. Groundwater samples collected from monitoring well EPA MW-09 contained elevated concentrations of dissolved arsenic (0.165 mg/L), cadmium (0.152 mg/L), lead (0.131 mg/L) and other metals (e.g., copper) (Ebasco, 1990). Concentrations of unfiltered metals were also elevated. Low concentrations of LPAHs (e.g., naphthalene at 6 $\mu g/L$) were detected in the groundwater sample. Metals concentrations were significantly lower in EPA MW-10. Organic compounds were not detected in EPA MW-10. Groundwater samples were analyzed for TCL parameters.

Elevated concentrations of dissolved and total cadmium (9.6 and 9.63 mg/L, respectively), dissolved and total lead (0.32 and 1.6 mg/L, respectively) and total sulfate (5,300 mg/L) in groundwater were detected primarily in the southeast section of the property (Batelle, 1989). The shallow groundwater samples contained higher lead and cadmium concentrations than the lower groundwater samples. Groundwater samples were analyzed for dissolved and total arsenic, cadmium, copper, lead, nickel, and zinc, specific conductance, pH, and sulfate.

Heavy metals such as arsenic (6 mg/L), cadmium (0.67 mg/L), and lead (1.3 mg/L) were detected in monitoring wells located in the southeast portion of the property (Hart Crowser, 1986 and 1987). Groundwater pH was generally lower in samples obtained from wells located in this area. Analysis of groundwater samples for total organic carbon (TOC) and total organic halogen (TOX) show low concentrations of organic constituents. Groundwater samples were collected from various monitoring wells (MW-1 through MW-12) at quarterly intervals from October 1985 through February 1988. The samples were analyzed for electrical conductance, pH, TOC, TOX, sulfate, and dissolved metals.

Texaco Bulk Terminal

The results of EPA's Remedial Investigation of Harbor Island and Groundwater Technology's petroleum leak investigations at the Texaco bulk storage terminal have indicated petroleum hydrocarbon compounds in soils and groundwater at several locations on the property.

In 1988 and 1989 as part of EPA's RI, two soil borings (EPA BH-05 and EPA BH-06) were drilled just south of Texaco's property. The borings were converted to monitoring wells EPA MW-05 and EPA MW-06—one shallow well (screened from a depth of 4.5 to 14.5 feet below grade) and one deep well (screened from a depth of 56.5 to 66.5 feet below grade) (Ebasco, 1990).

In 1986, Groundwater Technology under contract with Texaco U.S.A. installed seven observation wells (No. 1 through No. 7) and one product recovery well at Texaco's north farm terminal on Harbor Island to assess the extent of petroleum compounds associated with a diesel fuel leak from an underground pipeline. The observation wells were screened at depths between 2 and 22 feet).

Earlier, Groundwater Technology (1985) installed fourteen observation wells and one product recovery well at the Texaco Sales Terminal to assess the extent of petroleum compounds in groundwater associated with a line leak near a diesel fuel storage tank. The observation wells were screened between the ground surface and a depth of 14 feet.

Soil Quality Findings. Although petroleum odors were detected in the borehole while drilling EPA BH-05, organic compounds were not detected in the soil samples (Ebasco, 1990). Low concentrations of some metals (e.g., arsenic and lead) were detected in the soils samples. Soil samples were analyzed for TCL parameters with the exception of pesticides and PCBs. Soils samples collected from boring EPA BH-06 were not chemically analyzed.

Soil samples were not collected or analyzed during the Groundwater Technology investigations at Texaco.

Free Petroleum Product Findings. In 1985, Texaco reported the loss of 2,500 gallons of diesel fuel from an underground pipeline at the north farm terminal (Groundwater Technology, 1986). Soon after the spill, a recovery well was installed, and approximately 2,550 gallons of diesel product and water were removed from the ground.

In 1984, an undisclosed volume of diesel fuel leakedfrom an underground pipeline near a diesel fuel tank located at the Texaco Sales Terminal (Groundwater Technology, 1985). Groundwater Technology detected free (floating) product with thicknesses of 0.3 foot to 3 feet in five of the fourteen observation wells installed on the property. The product plume covered an approximate area of 22,000 ft^2. As of early 1986, approximately 7,000 gallons of diesel product and water had been removed via a product recovery well.

Groundwater Quality Findings. Monitoring well EPA MW-05 had the highest concentrations of toluene (320 $\mu g/L$), ethylbenzene (730 $\mu g/L$), and total xylenes (3,400 $\mu g/L$) detected in groundwater on Harbor Island (Ebasco, 1990). Low concentrations of naphthalene (9 $\mu g/L$) and some metals (e.g., lead) were also detected in EPA MW-05. Relatively lower concentrations of metals, with the exception of dissolved chromium (50.4 $\mu g/L$) and zinc (262 $\mu g/L$), were detected in EPA's deep well MW-06. Organic compounds were not detected in EPA MW-06. Groundwater samples were collected from EPA MW-05 and EPA MW-06 and analyzed for TCL parameters.

Groundwater was not chemically analyzed during Groundwater Technology's site investigations. However, the petroleum recovery systems installed at both locations recovered thousands of gallons of diesel fuel.

NATURE AND EXTENT

In this section we summarize information from the previous sections and interpret potential health and environmental effects. Compound types, affected media, potential migration pathways, and human and environmental receptors are discussed.

Types of Compounds and Affected Media

Based on the historical industrial activities and environmental assessments previously described in this report, the following areas have suspected and/or confirmed compounds in soils and/or groundwater.

Shell Bulk Storage Terminal

Based on historical activities, documented product releases, and compounds detected in adjacent EPA borings, suspected compounds in soil include:

- Petroleum hydrocarbons
- BETX
- Metals
- Semivolatiles

Similarly, based on historical activities, documented product releases, and compounds detected in adjacent EPA monitoring wells, suspended compounds in groundwater include:

- Petroleum hydrocarbons
- BETX
- Metals
- Semivolatiles

Shell A Yard Area

Based on historical activities and documented product releases, suspected compounds in soil include:

- Petroleum hydrocarbons
- BETX

Based on historical activities, documented product releases, and observations of free product in A Yard observation wells, suspected compounds in groundwater include:

- Petroleum hydrocarbons
- BETX

Leckenby Steel (Now Clough Industries) and Dimensional Engineering

While no soil or groundwater quality data are available at this site, historical activities may have released the following compounds to soil and/or groundwater:

- Petroleum hydrocarbons
- Metals
- Solvents
- PCBs

Seafab Metals

Based on historical activities and existing soil and groundwater quality data, suspected compounds in soil include:

- Arsenic
- Lead
- Cadmium

And in groundwater include:

- Arsenic
- Lead
- Cadmium
- Copper

- LPAHs
- Sulfate

Texaco Bulk Fuel and Distribution Terminal

Based on historical activities, documented fuel releases, and existing soil and groundwater quality data, suspected compounds in soil include:

- Petroleum Hydrocarbons
- BETX
- Arsenic
- Lead

And in groundwater include:

- Petroleum Hydrocarbons
- BETX
- Lead
- Chromium
- Zinc
- Naphthalene

ARCO Bulk Fuel Terminal

Based on historical activities and existing soil and groundwater quality data, suspected compounds in soil include:

- Petroleum Hydrocarbons
- B E TX
- Lead
- Trichloroethene

And in groundwater include:

- Petroleum Hydrocarbons
- BETX
- Arsenic
- Lead
- Mercury
- 2-Methylnaphthalene

Terminal 18

Based on historical activities, documented fuel releases, and existing soil and groundwater quality data, suspected compounds in soil include:

- Petroleum Hydrocarbons
- BETX

And in groundwater include:

- Petroleum Hydrocarbons
- BETX
- Lead

Seattle Iron and Metals

Based on historical activities and existing soil and groundwater quality data, suspected compounds in soil include:

- Lead
- Mercury
- Chlorinated Hydrocarbons
- PAHs
- PCBs

And in groundwater include:

- Arsenic
- Chromium
- Cadmium
- Lead
- Chlorinated Hydrocarbons
- LPAHs
- Acetone
- Benzene
- Benzoic Acid

Potential Migration Pathways—Shell Bulk Storage Terminal

Suspected compounds in the soil and groundwater beneath the Shell Bulk Storage Terminal may have originated as spills or leaks from several source areas, including:

- Above-ground storage tanks within the B and C Yards (Table 4);
- Former and existing underground storage tanks within the B, C, D, and E Yards (Figure 5);
- Below grade valve pits within the D Yard (Figure 5);
- Former and existing oil/water separators within the C and D Yards (Figure 5);
- Drums stored within the D Yard; and
- Underground utilities within the B, C, and D Yards (Figure 5).

These compounds may migrate via the pathways shown on the conceptual site model provided on Figure 13. Pathways include:

- Infiltration through soils;
- Groundwater transport;
- Underground utility conduits;
- Volatilization; and
- Wind blown dust.

These potential migration pathways are discussed below. No surface water bodies or residential drinking water wells are located within the bulk storage terminal area.

Infiltration Through Soils

Compounds which may have spilled or leaked from potential source areas may have infiltrated into the underlying soils. These compounds may be adsorbed onto soils within the vadose zone, may be migrating downward via gravity, or may have migrated to the underlying groundwater table.

Groundwater Transport

Compounds which have been transported from soils in the vicinity of historical leaks or other sources to the underlying groundwater may migrate in the general direction of local groundwater flow as depicted on Figure 14.

Underground Utility Conduits

Subsurface utility trenches and other structures represent potential pathways of groundwater flow, and hydrocarbon accumulation and migration. Figure 5 is a schematic map showing the distribution of water and sewer utilities, product pipelines, and other underground conduits on the Shell site and adjacent properties. While the utility trenches and other subsurface structures are not expected to affect the overall groundwater flow pattern near the Shell terminal, they may accelerate the potential for on- or off-site compound migration. In addition, the location of the numerous subsurface utilities, product/slop pipelines, and underground storage tanks present within the Shell terminal may complicate the distribution of petroleum hydrocarbons in groundwater beneath the site.

Water and sewer utilities, and many of the underground oil pipelines have surrounded the site since the 1930s and 1940s. The subsurface sewer pump station and sump located between the A Yard and Seafab Metals (near the intersection of SW Lander St. and 13th Ave. SW) have been in place since at least the 1960s. The invert elevation of the sump is about 20 feet below street grade.

Volatilization

Volatile compounds, namely BETX, may emanate from existing storage structures and areas potentially affected by historical leaks or spills.

Wind Blown Dust

An additional migration pathway is the historical fallout of wind blown dust from the Non-Ferrous Metals, and possibly the former Quemetco/Northwest Lead facilities. Although baghouse dust control measures were in place during at least a portion of the Quemetco ownership, it is uncertain when dust collection practices commenced.

Potential Receptors and Environmental Effects

Based on the known nature and extent of suspected compounds at the Shell bulk storage terminal, several potential human and environmental receptors may be identified.

Human exposure to petroleum hydrocarbon and BETX may occur via direct contact with and/or ingestion of potentially affected soils. Humans may also be exposed to the inhalation of volatile compounds, namely BETX, that may emanate from site soils and groundwater. While direct contact with groundwater at the site is possible, it is unlikely that groundwater will be ingested by humans at Harbor Island. The groundwater beneath Harbor Island is not a current drinking water source.

Environmental exposure to petroleum hydrocarbon and BETX appears to be principally limited to groundwater discharging into the surface waters surrounding the island. Groundwater discharges may potentially affect the quality of the Duwamish Waterways and Elliott Bay.

Preliminary Data Gaps

Based on the initial understanding of the conceptual site model and suspected compounds at the Shell Bulk Storage Terminal, several data gaps may be identified. They include:

- Vertical and lateral extent of suspected compounds in site soils;
- Vertical and lateral extent of suspected compounds in groundwater beneath the site; and
- Determination whether the site groundwater is a potential future drinking water source.

These issues will be addressed in the forthcoming Remedial Investigation Work Plan.

LIMITATIONS

Work for this project was performed, and this report prepared, in accordance with generally accepted professional practices for the nature and conditions of the work completed in the same or similar localities, at the time the work was performed. It is intended for the exclusive use of Shell Oil Company for specific application to the referenced property. This report is not meant to represent a legal opinion. No other warranty, express or implied, is made.

Any questions regarding our work and this report, the presentation of the information, and the interpretation of the data are welcome and should be referred to the undersigned.

We trust that this report meets your needs.

Sincerely,

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